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for the period February 1, 1964 to March 31, 1964

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PASADENA, CALIFORNIA

April 30, 1964

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Preface

The *Space Programs Summary* is a six volume, bimonthly publication designed to report on JPL space exploration programs, and related supporting research and advanced development projects. The subtitles of all volumes of the *Space Programs Summary* are:

- Vol. I. The Lunar Program (Confidential)
- Vol. II. The Planetary–Interplanetary Program (Confidential)
- Vol. III. The Deep Space Instrumentation Facility (Unclassified)
- Vol. IV. Supporting Research and Advanced Development (Unclassified)
- Vol. V. Supporting Research and Advanced Development (Confidential)
- Vol. VI. Space Exploration Programs and Space Sciences (Unclassified)

The *Space Programs Summary,* Volume VI consists of: an unclassified digest of appropriate material from Volumes I, II, and III; original presentation of the JPL Space Flight Operations Facility development progress; and a reprint of the space science instrumentation studies of Volumes I and II.

W. H. Pickering

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Jet Propulsion Laboratory

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PROPULSION DIVISION

I. Solid Propellant Engineering

A. Berylliumized Propellant Evaluation

R. L. Bailey and J. I. Shafer

A number of organizations are currently developing berylliumized propellants because they offer a significant gain in specific impulse over aluminized propellants. These propellants could, potentially, produce an improvement in payload capability for many applications provided the higher specific impulse were, indeed, realized and provided that nozzle erosion did not compel the use of excessively heavy nozzle designs or produce intolerable thrust misalignments.

A survey of static test firings reported by organizations working with different berylliumized propellants revealed that nozzle erosion rates varied markedly from propellant to propellant. Attempts to correlate erosion rates with propellant flame temperature, oxidation ratio, chamber pressure, or other parameters proved fruitless; unfortunately, the assessment was complicated excessively because the motor designs and test parameters differed appreciably from test to test.

A program has been initiated, therefore, to evaluate, under identical test conditions, three types of berylliumized propellants which are well along in their characterization: (1) a double-base type, (2) a composite type, and (3) a nitroplasticized-composite type. Their aluminum chemical analogs will also be tested in order to provide a frame of reference. The purpose of the program is to determine on a common basis:

(1) The sea level ballistic performance of these propellants.

(2) The effect, in a gross sense, of their combustion products on the erosion of a nozzle of standard design.

Because of the toxic nature of the propellant combustion products, arrangements have been made to use the

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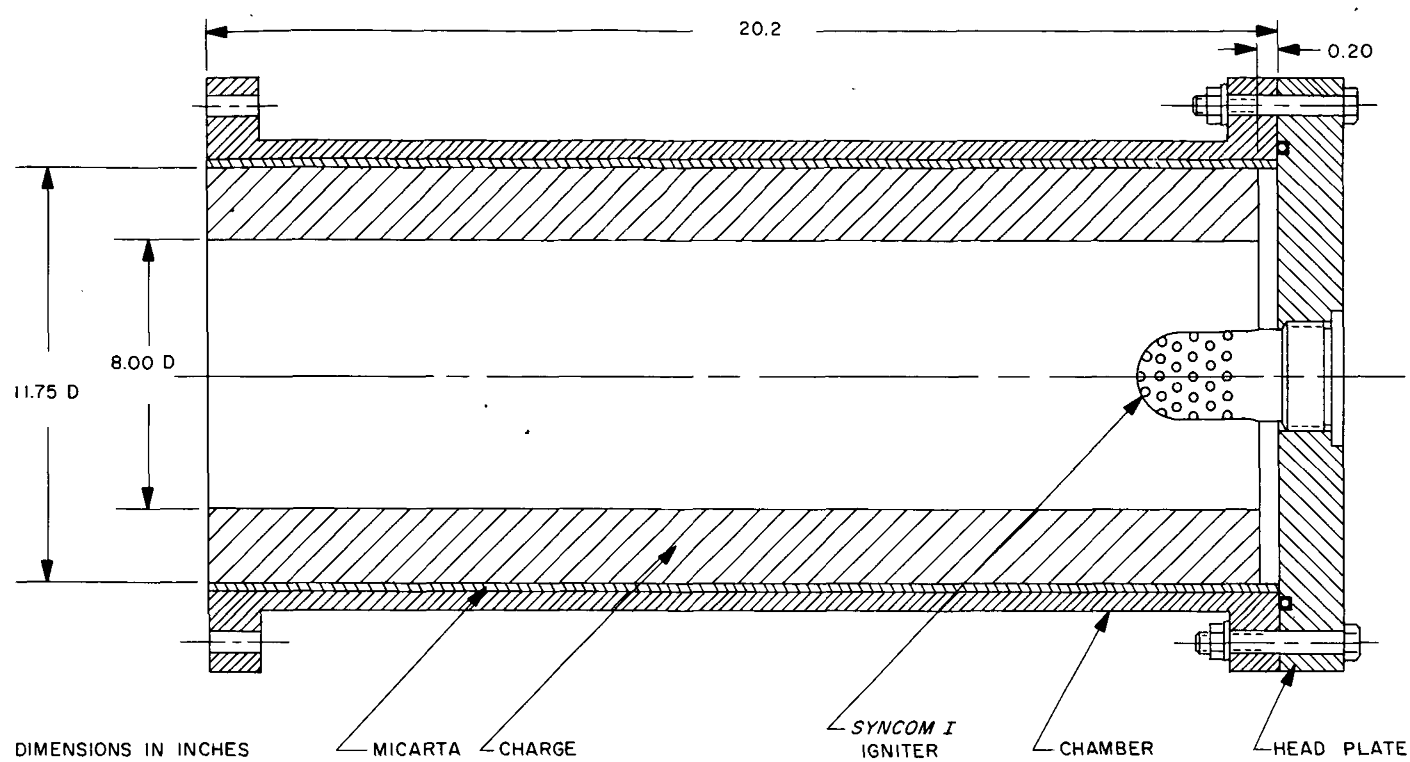

Fig. 1. Chamber *Syncom I* igniter and charge configuration for BATES motor

toxic test facility of the Air Force Rocket Propulsion Laboratory (AFRPL) at Edwards Air Force Base in a cooperative effort wherein the Jet Propulsion Laboratory would supply industrially-produced propellant charges for static firing in the ballistics test evaluation system (BATES) motor (Ref. 1) at AFRPL.

Fig. 1 shows a cross-sectional drawing of the BATES motor and Table 1 lists some nominal values for test parameters. Consideration is being given to substitution of the JPL 60-g *Syncom 1* igniter for the regular BATES M-8 igniter in an effort to keep the ignition delay to a minimum.

Because the existing instrumentation at the toxic facility is based on an analog system and presently limited to essentially 1% measurement precision, the equipment will be modified to incorporate JPL voltage-to-frequency converters. This conversion to a digital system should upgrade instrument precision to better than 0.5%.

Table 1. Nominal values for BATES motor[a] parameters

Parameter	Value
Propellant weight, lb	$\approx$ 68
Expansion area ratio	(Optimum)
Port-to-nozzle-throat ratio	$>$ 15
Chamber pressure, psi	600
Burning time, sec	$\approx$ 7 to 8

[a] Charge configuration is cartridge tubular (constant pressure).

Three berylliumized charges and one aluminized chemical analog will be procured for tests from each of three manufacturers: Aerojet-General Corporation, Thiokol Chemical Corporation, and Atlantic Research Corporation. Two additional charges of Thiokol's aluminized propellant, the *Surveyor* retro-motor propellant, will be tested to check reproducibility of the system and to establish a reliable reference point for comparison.

The same nozzle design will be used for all aluminized charges and one of each of the berylliumized charges. Fig. 2 shows a cross-sectional drawing of the nozzle. If these static firings are satisfactory, the two remaining charges from each company will be used to evaluate nozzle materials. Several alternate nozzle designs are being reviewed for this purpose at the present time.

Contracts for all 14 charges have been let, the 4 charges from Aerojet have been delivered, and the first static test firing is scheduled for late in April.

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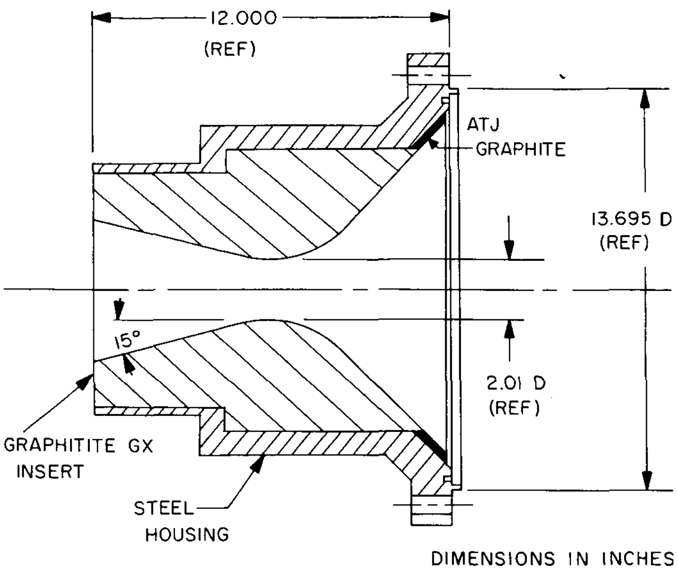

Fig. 2. Nozzle design for evaluating beryllium propellant performance

B. Advanced Technological Satellite Motor Development

R. L. Haserot

1. Introduction

In January 1963 the Jet Propulsion Laboratory initiated a developing program to provide a solid propellant apogee rocket motor for a second generation *Syncom* satellite. This program was under the management of the Goddard Space Flight Center and was designated Advanced *Syncom*. It was to result in a spin stabilized, active repeater communication satellite weighing about 750 lb, operating at synchronous altitude (22,300 mi) which would handle voice communications, teletype, and monochrome and color television signals.

Recently, the Advanced *Syncom* communication program has been redirected to include a number of experimental instruments in addition to the original communication instruments. This expanded program has been named the Advanced Technological Satellite (ATS) Program and will result in a general purpose satellite capable of operation at synchronous altitude with experimental instruments in the areas of meteorology, communications, radiation, navigation, gravity gradient stabilization, and various engineering experiments. For these satellites to be placed in synchronous orbit, JPL will provide a solid propellant rocket motor to provide the final required velocity increment at the apogee of the elliptical transfer orbit. This rocket motor, formerly called Advanced *Syncom*, has been redesignated the JPL-SR-28-1 rocket motor.

Developmental progress for this motor has been reported bimonthly since *SPS 37-20*, Vol. V.

2. Development Program Status

The motor development program calls for static firing of 4 heavywall motors and 15 flightweight motors prior to conducting a 9-motor qualification program. To date, the four heavywall motor tests have been completed. The results of these tests were summarized in Ref. 2. The first two flightweight motors were static fired under sea level conditions and results are reported herein. The development program should be completed during 1964.

3. Flightweight Motor Static Firings

The first two flightweight motors were processed and static fired under sea level conditions at the JPL Edwards Test Station facility. The motor components were identical with the exception that on the second test a very lightweight aluminum igniter basket was utilized.

The motor chambers were of the flightweight design. Each had been proof pressure tested, prior to insulating, to 285 psi for 5 min.

The chambers were insulated with 10.4 lb of Gen-Gard NBR V-52, an acrylonitrile butadiene co-polymer compound. The sheet material was hand layed up to achieve thicknesses varying from 0.170 to 0.030 in. and then cured in place under heat and pressure.

The nozzles tested on these motors were flight design except that the expansion ratio was 8.5:1 for a sea level firing rather than the 35:1 design contemplated for flight use. The nozzle body thickness used in these tests was based on information from the heavywall motor tests.

The igniter design was basically the same as tested on the heavywall motor tests. A consumable aluminum basket was used on both tests. On the second test this basket had been pared down to a minimum weight for evaluation.

The motors were cast with approximately 760 lb of JPL-540 propellant. The propellant was cast directly against the insulation after first treating the rubber surface with a toluene diisocyanate–methylene chloride solution.

Instrumentation for the tests consisted of 2 channels of chamber pressure, 1 channel of igniter pressure, 2 channels of axial thrust, and 20 channels of thermocouples to record various motor temperatures. In addition, microphones and accelerometers were mounted on the test stand and in the test cell to record motor vibration and noise output.

Table 2. Flightweight motor data summary

Motor number	P-2	P-7
Code designation	C-1	C-2
Run number	E-127	E-129
Test date	2-26-64	3-5-64
Grain temperature, °F	60	60
Propellant weight, lb	761	761
Initial chamber pressure, psia	104	99
Peak chamber pressure, psia	265	261
Ignition pressure, psia	257	175
Run time, sec	42.4	43.0
Throat erosion, %	1.77	1.82
W^*_{av} (performance based on chamber pressure)	4974	4971

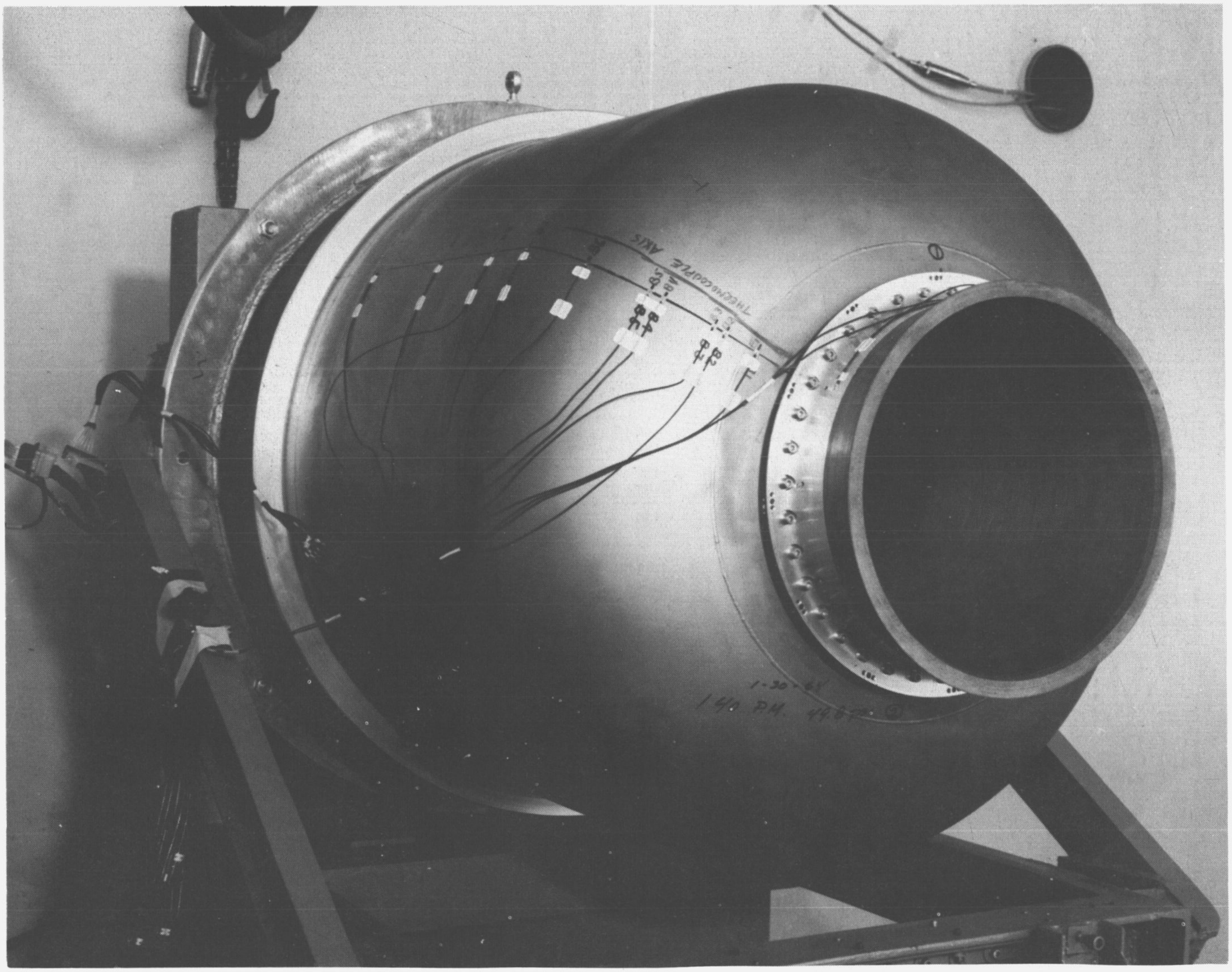

Fig. 3. Motor P-2 before firing test (Run E-127)

Both motor firings were successful. All motor components were in excellent condition after the test. A summary of motor performance data is given in Table 2. The pressure-time trace for the second run, E-129, showed a pressure spike at 1.8 sec, indicating a large piece of the lightweight igniter basket was ejected intact.

Seventeen thermocouples recorded chamber temperatures during and after the motor firing. The temperatures for Chamber P-7 are shown in Table 3. Since these motors were tested under atmospheric pressure conditions, the temperatures are probably somewhat lower than those expected during testing under high altitude or vacuum conditions due to the loss of heat by convection cooling at atmospheric pressure.

Figs. 3 and 4 show pre-fire and post-fire photographs of the first test, Run E-127.

Table 3. Chamber temperature for motor P-7 (Run E-129)

Thermocouple location and number		Temperature at end of run (43 sec), °F	Maximum recorded temperature/time, °F/sec
Head end	G-1	295	450/135
	G-2	375	525/100
	G-3	350	600/150
	G-4	420	605/110
	G-5	295	560/85
	G-6	335	540/100
	G-7	110	435/400
Nozzle end	B-1	435	630/90
	B-2	515	685/90
	B-3	525	700/85
	B-4	410	655/80
	B-5	425	645/80
	B-6	155	480/160
	B-7	95	445/220
Cylinder	B-8	100	495/185
	B-9	100	510/130
	B-10	100	455/350

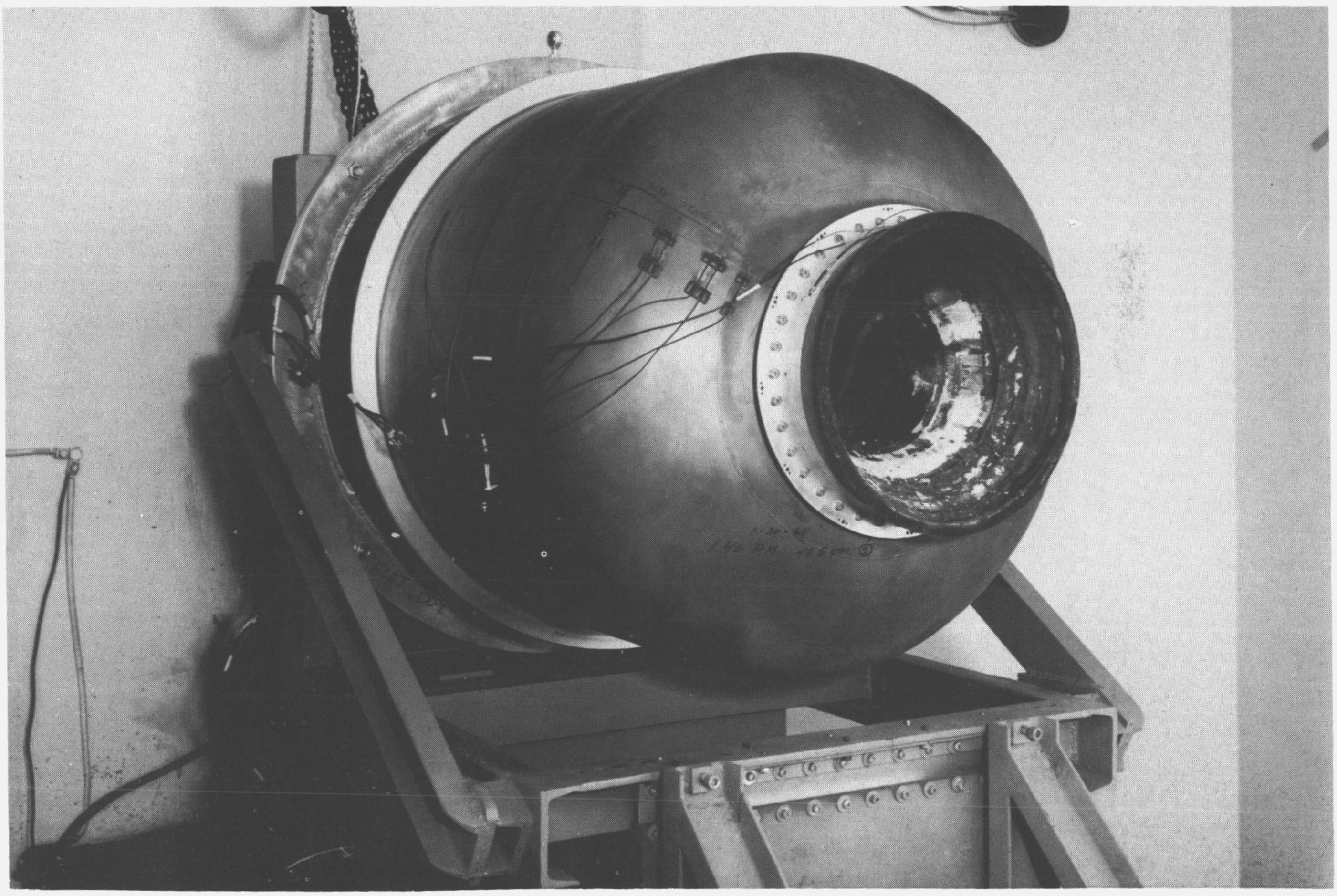

Fig. 4. Motor P-2 after firing test (Run E-127)

4. *Flightweight Chamber Post-Fire Inspection*

Flightweight Chambers P-2 and P-7 were inspected for critical alignment data after static firing to determine if the firing or heating permanently distorted the chambers enough to affect the data. The surfaces inspected were:

(1) A1, which centers the motor in the spacecraft.

(2) B1, which holds the motor axis parallel to the spacecraft and axis.

(3) A2, which centers the nozzle on the chamber.

(4) B2, which holds the nozzle axis parallel to the chamber axis.

Results of inspections showed motor firing and post-firing heating had no effect on the critical alignment of the motor chambers.

5. *5 × 13 Batch Check Motor*

Eighteen 5 × 13 batch check motors containing approximately 12 lb of propellant have been cast from 6 propellant batches for ballistic evaluation. Three of these motors have been static fired, representing three batches of propellant. The variation in performance was less than 0.5%. It is felt that this variation may be reduced through tighter control of weights and measurements.

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2. Haserot, R. L., "Apogee Motor Development, Advanced *Syncom*," *Space Programs Summary No. 37-24*, Vol. V, pp. 5–9, Jet Propulsion Laboratory, Pasadena, California, December 31, 1963 (Confidential).